SANTA BARBARA TRAVEL DEMAND MODEL OVERVIEW

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March 2009

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INTRODUCTION

BACKGROUND

As part of the *Plan Santa Barbara* General Plan Update, the City of Santa Barbara (City) decided to develop a Travel Demand Forecasting (TDF) model to support this and other long-range transportation planning efforts. The City had not previously developed a model.

The purpose of this project is to develop the City model in the TransCAD Transportation Geographic Information System (GIS) software, create the key model inputs such as land use, road network and trip generation parameters, and validate the model to current (2008) conditions. The TDF model will be used in the update of the City's General Plan and could be used to generate traffic volume forecasts and other travel demand data for various planning and engineering studies.

Although there are seasonal variations in traffic in Santa Barbara due to tourist visitations and resident vacations, the model was calibrated and validated to average mid-week traffic. The land use data, roadway network, and traffic counts reflect March 2008 conditions. Care was taken to avoid school spring breaks, inclement weather, and other major disruptions to traffic. The resulting data represent travel during a period when people in Santa Barbara are participating in their normal day-to-day activities.

The purpose of this report is to introduce the interested citizens, elected and appointed officials of the City of Santa Barbara to their travel demand model. It describes the model development process in general, and how this process was applied to develop the City of Santa Barbara TDF model, including the sources of data used to develop key model inputs.

GENERAL DISCUSSION OF THE TDF MODEL

This section summarizes the answers to commonly asked questions related to TDF models and how the City can use a TDF model.

What is a TDF Model?

A TDF model is a computer program that simulates traffic levels and patterns for a specific geographic area. The program consists of input files that summarize the area's land uses, street network, travel characteristics, and other key factors. Using this data, the model performs a series of calculations to determine the amount of trips generated, where each trip begins and ends, and the route taken by the trip. The model's output includes projections of traffic volumes on major roads, and peak hour turning movements at certain key intersections.

How is a TDF Model Useful?

The City TDF model will be a valuable tool for the preparation of long-range transportation planning studies, such as the *Plan Santa Barbara* General Plan Update. The travel model will be used to estimate the average daily and peak hour traffic volumes on the major roads in response to future land use, transportation infrastructure, and policy assumptions, and form a consistent basis by which to analyze the different potential land use scenarios. Additionally, using these traffic projections, transportation improvements will be identified to accommodate the changing traffic patterns associated with the general plan's preferred land use alternative.

How do we know if the TDF Model is Accurate?

To be deemed accurate for projecting traffic volumes in the future, a model must first be calibrated to a year in which actual land use data and traffic volumes are available and well documented. A model is accurately calibrated when it replicates the actual traffic counts on the major roads within certain ranges of error established in the "Travel Forecasting Guidelines," (Caltrans, 1992) and it demonstrates stable responses to varying levels of inputs. The City TDF model has been calibrated to 2008 (base year) conditions using actual traffic counts, census data, and land use data compiled by City staff.

Is the City of Santa Barbara TDF Model Consistent with Standard Practices?

The City of Santa Barbara TDF model is consistent in form and function with the standard traffic forecasting models used in the transportation planning profession. The model includes a land use/trip generation module, a gravity-based trip distribution model, and a capacity-restrained equilibrium traffic assignment process. The travel model utilizes Version 5.0 of the TransCAD Transportation GIS software, which is consistent with many of the models used by local jurisdictions in California and throughout the nation. The Santa Barbara County Association of Governments (SBCAG), the Metropolitan Planning Organization for Santa Barbara County, maintains the current regional travel demand model in TransCAD.

How Can the TDF Model be Used?

The TDF model can be used for many purposes related to planning and design of the City's transportation system. The following is a partial listing of the potential uses of the TDF model:

- To update the General Plan
- To update the Street Master Plan
- To update the city-wide traffic impact fee program
- To evaluate the traffic impacts of area-wide land use plan alternatives
- To evaluate the shift in traffic resulting from a roadway improvement
- To evaluate the traffic impacts of land development proposals
- To determine trip distribution patterns of land development proposals
- To support the development of transportation sections of Environmental Impact Reports (EIRs)
- To support the preparation of project development reports for Caltrans

STUDY AREA AND ROADWAY CLASSIFICATION

Figure 1 shows the study area for the City travel demand forecasting model. The model area encompasses the City of Santa Barbara and portions of neighboring unincorporated County areas which are in or near the City's Sphere of Influence. The study area contains all areas that may experience land use changes under *Plan Santa Barbara* and areas directly adjacent that interact frequently with the City and its Sphere of Influence.

SUMMARY OF THE INPUT DATA

DATA COLLECTION

A comprehensive data collection effort was undertaken at the outset of the *Plan Santa Barbara* process. The results of this effort are largely contained in the *Plan Santa Barbara: Transportation Existing Condition Report* (AMEC, 2008). This report served to guide the overall model development process by documenting the demographic profile, commute patterns, travel trends and traffic conditions which currently exist in Santa Barbara. In addition, certain data from this report were used directly in the model development process, such as traffic counts and household vehicle ownership data.

Other data sources include SBCAG for roadway network and regional travel data, Caltrans and the County of Santa Barbara for traffic count data, and the City of Santa Barbara for land use, and roadway network data.

LAND USE DATA

Land use data is one of the primary inputs to the travel model. These data are instrumental in estimating trip generation. This model primarily uses the City's parcel-level land use database (maintained in a GIS format) as the source for information on how much development currently exists within each traffic analysis zone (TAZ). These data were supplemented by County parcel-based data and SBCAG TAZ-based data for areas in and bordering the Sphere of Influence.

Land use in the model is divided into a variety of residential and non-residential categories. The City of Santa Barbara TDF model employs twenty-eight land use data categories to describe land use in the City, as shown in Table 1.

TRAFFIC ANALYSIS ZONE SYSTEM

Travel demand models use traffic analysis zones (TAZs) to subdivide the study area for the purpose of connecting land uses to the road network. The TAZs represent physical areas containing land uses that produce or attract vehicle-trip ends. Since the Santa Barbara County Association of Governments (SBCAG) is the Metropolitan Planning Organization (MPO) for the area, the TAZ system for the Santa Barbara model was developed to nest within the regional model TAZ system. After reviewing the TAZ layer used in the SBCAG regional model, along with the roadway network and recent aerial photographs, a set of TAZ boundaries was created for the Santa Barbara model to achieve the following local area enhancements.

- A number of large TAZs were subdivided which allows for a more detailed assignment of local traffic to the highway network. This level of detail is necessary to forecast traffic volumes at the turning movement level.
- Considerable detail was added to the TAZ system in the downtown street grid to allow for a detailed traffic assignment and a more accurate calculation of the 4D variables.
- TAZs were created to be consistent with large developments such as Paseo Nuevo and La Cumbre Plaza.

The resulting 2008 model TAZ system includes 460 zones in the model area. Detailed maps showing the TAZ numbers in all portions of the model area are included in Appendix A. Also included in the TAZ structure are the external stations or gateways at points where major roadways provide access into the model area. The external gateways represent all major routes by which traffic can enter or exit the study

TABLE 1
MODEL LAND USE CATEGORIES

Land Use Type	Units
Residential	
Land Use Type	**Units**
Single-Family (SF)	Dwelling Units
Multi-Family Zero Cars (MF_0)	Dwelling Units
Multi-Family One Car (MF_1)	Dwelling Units
Multi-Family Two Cars (MF_2)	Dwelling Units
Multi-Family Three or More Cars (MF_3P)	Dwelling Units
Non-Residential	
Land Use Type	**Units**
Commercial Services	Thousand Square-feet
Entertainment	Thousand Square-feet
Auto Related	Thousand Square-feet
Restaurant	Thousand Square-feet
Retail	Thousand Square-feet
Lodging	Thousand Square-feet
Office	Thousand Square-feet
Institutional	Thousand Square-feet
Industrial	Thousand Square-feet
Hospital	Thousand Square-feet
Religious Facilities	Thousand Square-feet
Police and Fire Services	Thousand Square-feet
Elementary and Middle School	Students
High Schools	Students
Colleges	Students
Recreation (Parks and Beaches)	Relative Popularity[2]
Golf	Acres
SBCAG_Agricultural[1]	Employees
SBCAG_Industrial[1]	Employees
SBCAG_Commercial[1]	Employees
SBCAG_Office[1]	Employees
SBCAG_Service[1]	Employees

[1] Data adapted from SBCAG TAZs uses SBCAG units of employment.

[2] Recreational trips are generated at the home end (either Residential or Lodging) and distributed to the various Recreational areas of the City based on their relative popularity. Relative popularity was calibrated using count data near the recreational sites.

Source: Fehr & Peers, 2008.

area and capture the traffic entering, exiting, or passing through the model area. Table 2 contains a list of the eight external gateways numbered from 1001 to 1010 that were established for this model.

ROADWAY NETWORK

The roadway network for the base year conditions is based on the SBCAG's GIS roadway centerline file. The model roadway network includes all State Routes; arterials, collectors, and a selection of local roads within the study area (see Figure 1).

The roads shown in Figure 1 are classified in four major categories and form the primary road network that is represented in the model structure. As is typical for urban-area models, the model network focuses on facilities in the higher functional classes and does not attempt to replicate travel patterns on local residential streets, but does include some of them to distribute traffic. The travel model includes eight external stations to represent travel to and from areas outside of the City. The four major road categories are described below.

Freeways: Freeways are high-capacity facilities that primarily serve long-distance travel. Access is limited to interchanges that are typically spaced at least one mile apart. US-101 is the freeway which runs directly through the Santa Barbara model area. SR 217, which is west of the study area, connects UCSB and the Santa Barbara Airport to US-101.

Highways: Roadways designated as highways are typically State highways that are not limited-access freeways. These facilities serve travel between Santa Barbara and neighboring cities. The primary highway in Santa Barbara is SR 154. SR 192 runs generally parallel to US-101 along the foothills north of the City.

Arterials: Roadway segments classified as arterials are major roads that provide connections within the City, between the City and neighboring areas, or through the City (cut-through traffic). Arterials in Santa Barbara typically have two lanes in each direction, with travel speeds of 35 miles per hour (mph). Arterials are further classified as Major or Minor. Section 3 contains details on the distinction between these classes.

Collectors: Collectors are facilities that connect local streets to the arterial and highway system, and may also provide direct access to some local land uses. Collectors typically have one lane in each direction, with speeds of around 25-30 mph.

The roadway network database received from SBCAG includes street name, distance, functional class, speed, capacity, and number of lanes. These attributes were checked using maps, aerial photographs, and other data provided by the City. Table 3 shows the initial roadway speeds, lanes and capacities used for each roadway class in the model. Where necessary, these values were then modified to reflect current conditions at specific locations.

Additional Roadway Attributes

For a representative sample of network links, current daily, AM peak hour, and PM peak hour traffic counts have been coded for validating the model. The traffic count data was collected from several sources including Caltrans, the County, the City, and a comprehensive set of traffic counts conducted in March, 2008.

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STUDY AREA AND ROADWAY FUNCTIONAL CLASSIFICATION

FIGURE 1

TABLE 2 EXTERNAL GATEWAYS	
Gateway Number	**Gateway Description**
1001	Hollister Avenue west of Turnpike Road
1002	US-101 west of Turnpike Road
1003	US-101 SB west of Turnpike Road (not used - combined with 1002)
1004	Cathedral Oaks Road west of Turnpike Road
1005	State Route 154 north of State Route 192
1006	State Route 192 west of Sheffield Drive
1007	Sheffield Drive north of Ortega Hill Road
1008	Ortega Hill Road east of Ortega Ridge Road
1009	US-101 east of Sheffield Drive
1010	US-101 SB east of Sheffield Drive (not used - combined with 1009)

Source: Fehr & Peers, 2008.

TABLE 3
TYPICAL ROADWAY SPEEDS AND CAPACITIES

Roadway Classification [1]	Speed (MPH)	Total Through Lanes	Lane Capacity (Vehicles per hour per lane)	Total Facility Capacity (Vehicles per hour)
Freeway	65	4	2,000	8,000
Highway	50	4	1,200	4,800
Major Arterial	35	4	900	3,600
Minor Arterial	35	4	750	3,000
Collector	30	2	600	1,200
Local	25	2	600	1,200
Ramp	30	1	1,800	1,500
Centroid Connector[2]	30	2	10,000	20,000

[1] SBCAG, 2004.
[2] Centroid connectors are abstract representations of the starting and ending point of each trip, and thus should have no capacity constraints.
Source: Fehr & Peers, 2008.

DESCRIPTION OF THE MODEL CALIBRATION PROCESS

Model calibration is the process by which parameters are set based on a comparison of travel estimates computed by the model with actual data from the area being modeled. This section provides a general description of the calibration steps and the adjustments made during the process to achieve accuracy levels that are within Caltrans' guidelines.

TRIP GENERATION RATES

Trip generation rates relate the number of vehicle trips going to and from a site to some measure of the intensity of use at the site. Each trip has two ends, a "production" and an "attraction" end. By convention, trips with one end at a residence are defined as being "produced" by the residence and "attracted" to the other use (workplace, school, retail store, etc.), and are called "Home-Based" trips. Trips that do not have one end at a residence are called "Non-Home-Based" trips.

There are five trip purposes used in the Santa Barbara model:

1. Home-Based Work (HBW): trips between a residence and a workplace.
2. Home-Based Other (HBO): trips between a residence and any other destination.
3. Non-Home-Based (NHB): trips that do not begin or end at a residence, such as traveling from a workplace to a restaurant, or from a retail store to a bank.
4. Recreational (REC): trips to and from the beaches, parks and other attractions (such as the Mission) in the model area.

Trip generation rates are initially defined for total trips and later split by trip purpose, for both productions and attractions.

The most widely used source for individual project vehicle trip generation rates in the transportation planning field is the ITE *Trip Generation Manual*. This book contains national averages of trip generation rates for a variety of land uses collected by conducing driveway counts in what are generally suburban locations. The ITE land use categories tend to be very specific, while model land use categories (accounting for all land use in the City) tend to be more general. While ITE rates are appropriate for smaller site specific uses - such as traffic studies for development review - and can provide a starting point for travel models, capturing the interaction between all land uses in the City, in addition to the unique local characteristics of Santa Barbara requires the development of specific trip generation rates for the model.

A traffic impact study utilizes ITE trip generation rates because in most cases the project being examined shares characteristics with the information contained the *Trip Generation Manual*. In other words, both the traffic impact study and the ITE rates are going to rely on single-use, isolated projects that have plenty of free parking and little or no interaction with other nearby uses. When assessing the impact of an individual project, the ITE rates are typically appropriate since they can correctly mimic the site being analyzed in the traffic impact study.

The Santa Barbara TDF model, on the other hand, generates trips by purpose, and matches productions/attractions to have a balance. The model also has trip rates calibrated to local conditions and other advanced trip generation features such as cross classification that consider the effect of other variables such as vehicle availability. Traffic impact studies rely on ITE trip rates that only vary based on land use type or size. While they are a valid starting point for model calibration and validation, they have a different purpose and are not suitable for demand forecasting without customization.

Certain ITE rates will be more applicable to Santa Barbara model rates because they represent a comparable level of detail relative to what is contained in the model (e.g. "Office" = "Office"). Some ITE rates, however, cannot be used directly because the land use category is not the same as the City's land use classifications. For example, ITE's restaurant category has high turnover restaurant, fast food restaurant, fast food restaurant with drive-through with seating, fast food restaurant with drive through and no seating, etc. By necessity, Santa Barbara restaurant rates represent a compilation and average of those rates customized to the City. It is important to recognize that ITE rates are in fact averages based on driveway counts at multiple locations, so the utilization of average rates within the Santa Barbara model is entirely appropriate and accurate.

The 2008 trip generation rates were initially based on residential trip generation surveys, the SBCAG regional model, recently calibrated models in similar areas, and the ITE *Trip Generation Manual*. For example, we used as a starting point certain calibrated trip generation rates from San Luis Obispo and Lompoc. These areas were selected to the extent that they share at least partial socioeconomic and land use characteristics with the City of Santa Barbara. The rates were calibrated to account for local conditions based on counts, production-to-attraction balancing, and the difference between ITE and model land use definitions. So the final Santa Barbara trip generation rates are unique to the Santa Barbara model, and are ultimately based upon the results of successful model calibration and validation.

PRODUCTION/ATTRACTION BALANCING

Local trips (internal-to-internal, or I-I) are trips which both start and end in the study area. One of the basic assumptions of any travel model is that the total number of local trips produced is equal to the total number of local trips attracted. The logical assumption is that if someone starts on a journey from someplace they must end their journey someplace else. Otherwise, travelers would be disappearing into thin air. If the total productions and attractions are not equal, the model will typically adjust the attractions to match the productions (thus ensuring that each departing traveler finds a destination). While it is never possible to achieve a perfect match between productions and attractions prior to the automatic balancing procedure, the existence of a substantial mismatch in one or more trip purposes indicates that either land use inputs or trip generation factors may be in error.

Table 4 summarizes the local trip productions and attractions from the Santa Barbara travel model for each trip purpose, prior to the application of the automatic balancing procedure. Guidelines published by Federal Highway Administration's Transportation Model Improvement Program (TMIP) and National Highway Cooperative Research Program (NCHRP) suggest that, prior to balancing, the number of productions and attractions should match to within plus or minus 10% (i.e., the production-to-attraction ratio should be within the range of 0.90 to 1.10). The results shown in Table 4 indicate that the 2008 model meets the published guidelines for all trip purposes.

In addition to production and attraction balancing, the percent of total trips for each purpose were checked for reasonableness. Typical values are provided below:

- HBW trips 18% to 27% of all trips
- HBO trips: 47% to 54% of all trips
- NHB trips: 22% to 31% of all trips

While the Santa Barbara Model falls slightly outside of these ranges, the trip purpose percentages in the 2008 Santa Barbara model are generally reasonable and reflect a greater degree of trip chaining in Santa Barbara due to its long and narrow physical geography. This information, in conjunction with the trip generation rate comparisons and trip purpose distributions discussed later in this report, indicates that the trip generation component of the Santa Barbara model is performing reasonably.

FURTHER REFINEMENT

In addition to the standard trip generation procedures, certain enhancements were added to the Santa Barbara model to better capture local trip making characteristics and provide the ability to test certain policy options for future development scenarios. These enhancements include dividing the model area into four "area types" and cross-classifying multifamily households by auto-ownership.

Area Types

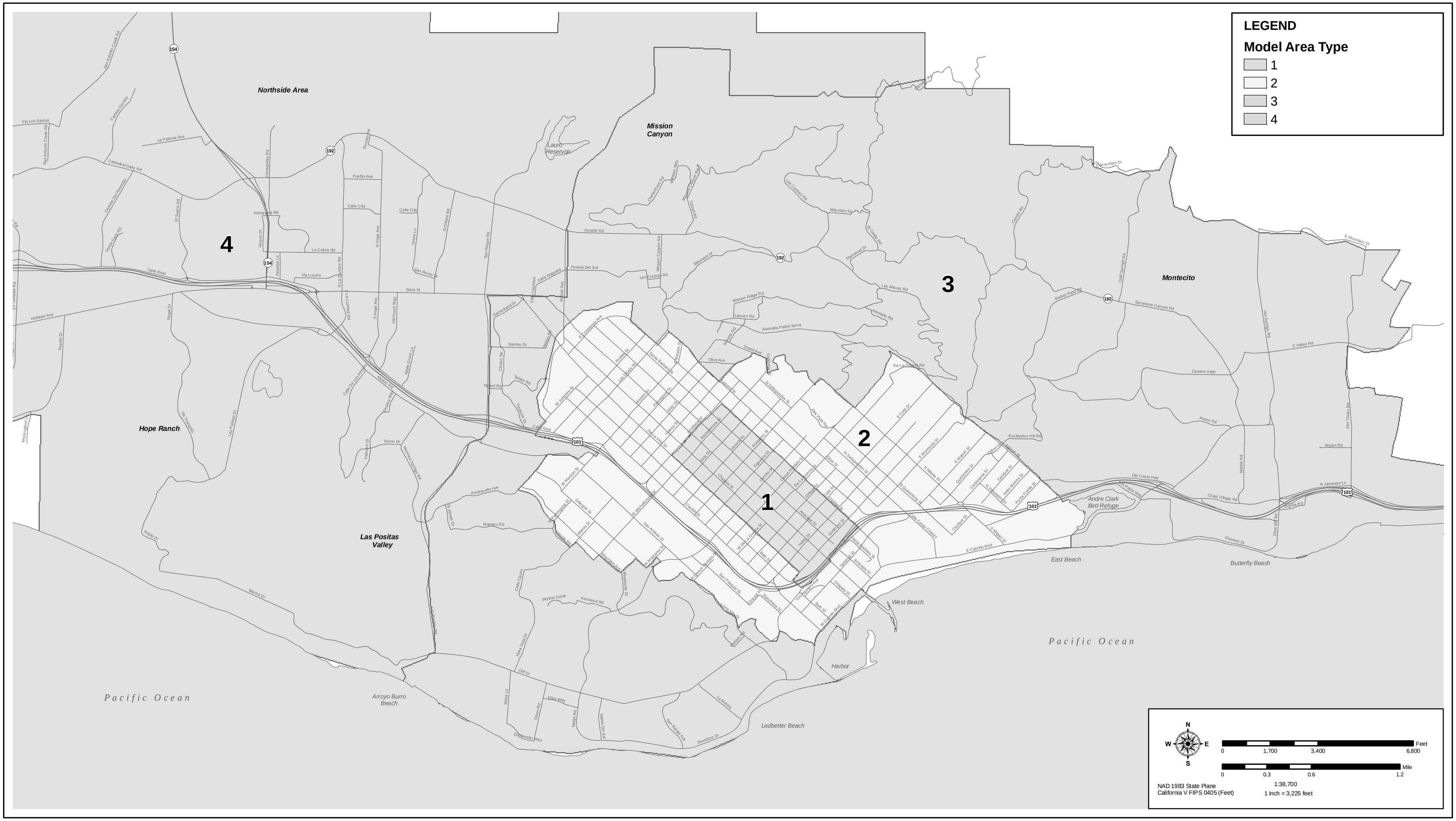
The model area contains a variety of development patterns, each with different land use characteristics and associated trip making patterns. To account for these differences, the model area was divided into four "area types". The four area types, which are shown in Figure 2, have their own associated trip generation rates and internal/external trip making characteristics.[1] Trip generation rates for each land use

TABLE 4
TRIP PRODUCTION TO ATTRACTION RATIOS BY PURPOSE

Trip Purpose	Production/ Attraction Ratio	Percent of Total Daily Vehicle Trips	
		2008 PlanSB model	California[1]
Home-Based Work (HBW)	1.00	15%	21%
Home-Based Other (HBO)	1.01	43%	48%
Non-Home-Based (NHB)	1.00	41%	31%
Recreational (REC)	N/A	2%	N/A
Total		101%	100%

[1] 2000-2001 California Statewide Household Travel Survey Final Report, June 2002.
Note: May not total 100% due to rounding
Source: Fehr & Peers, 2008.

[1] Internal/External trip making is explained in the Trip Distribution section below



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PLAN SANTA BARBARA MODEL AREA TYPES

FIGURE 2

in each area type are shown in Table 5. For reference, a table of ITE rates for which there are comparable land uses in the model is provided in Appendix B. Note that in some cases, Santa Barbara model rates are either higher or lower than the most applicable ITE rate. For example, the average ITE trip generation rate for single-family homes is 9.57 vehicle trips per day per unit. The Santa Barbara model single-family rates range from 8.05 to 11.98 vehicle trips per day per dwelling unit. The average ITE office rate, to provide another example, is 11.01 vehicle trips per day per thousand square feet. The Santa Barbara model rates range from 8.27 to 12.92 vehicle trips per day per thousand square feet.

As noted above, ITE trip generation rates for individual land uses can vary considerably from study to study, and ITE uses an average of these studies. For multi-family, for example, ITE does not provide stratification by auto-ownership – only a range from 4.18 to 6.72 vehicle trips per day per dwelling unit. The Santa Barbara model is based upon auto-ownership rates from the National Household Travel Survey (NHTS) specific to Santa Barbara. Both the levels of auto ownership, and the multi-family trip generation rates, are based upon the NHTS.

Area type 1 represents the Central Business District. This area contains the greatest concentration of commercial and retail land uses. In addition, it is generally coterminous with the Parking Zone of Benefit. These land uses are grouped together because of their similar density and their shared parking situation.

Area type 2 represents the remaining “grid” portion of the City. This area has older development patterns of connecting streets, smaller lots, and a mixture or residential and non-residential land uses.

Area types 3 and 4 are similar in development patterns and land use characteristics. They are generally residential areas with limited non-residential land uses. The primary difference between the two is the internal/external and external/internal trip making, which is mostly a function of geography. More trips from area type 3 remain in the study area. This is largely because it is the eastern end of developed land and the study area provides the most destinations for travelers from this area. Area type 4, which borders urbanized areas of the unincorporated county and is close to Goleta, has greater interaction with areas outside the model. In addition, area type 4 contains a regional retail center which attracts trips from outside areas.

Multi-Family Unit Vehicle Ownership

In order to test certain potential policy alternatives, multi-family dwelling units were divided into four types representing varying levels of automobile ownership. Auto-ownership data for each census tract in Santa Barbara was obtained from the 2000 National Household Travel Survey, which is conducted by the United States Census Bureau. The percentage of households representing each level of automobile ownership was calculated and the total number of multifamily units in each census tract was apportioned to the relevant multi-family trip generation category based on this percentage.

TRIP DISTRIBUTION (GRAVITY MODEL)

Once the trip generation step has determined the number of trips that originate and terminate in each zone, the trip distribution process determines the specific destination of each originating trip. The destination may be within the zone itself, resulting in an intra-zonal trip. If the destination is outside of the zone of origin, it is an inter-zonal trip. Internal-internal (I-I) trips originate and terminate within the model area. Trips that originate within but terminate outside of the model area are internal-external (I-X), and trips that originate outside and terminate inside of the model area are external-internal (X-I). Trips passing completely through the model area are external-external (E-E).

The trip distribution model uses the gravity equation to distribute trips to all zones. This equation estimates an accessibility index for each zone based on the number of attractions in each zone and a friction factor, which is a function of travel time between zones. Each attraction zone is given its pro-rata share of productions based on its share of the accessibility index. This process applies to the I-I, I-X, and X-I trips. The E-E trips are added to the trip table prior to final assignment.

Friction Factors

Friction factors, also known as travel time factors, determine the relative attractiveness of each destination zone based on the travel time between TAZs and the number of potential origins and destinations in each TAZ. These factors are used in the trip distribution stage of the model. The 2008 Santa Barbara model friction factors are based on data reported in national modeling reference documents such as National Cooperative Highway Research Program (NCHRP) 365, and modified based on local conditions and comparison with the SBCAG model. See Appendix C for friction factor curves.

TABLE 5
DAILY VEHICLE TRIP GENERATION RATE COMPARISON

Residential[1]					
Land Use Type	**Units**	**2008 PlanSB Model Area Type 1**	**2008 PlanSB Model Area Type 2**	**2008 PlanSB Model Area Type 3**	**2008 PlanSB Model Area Type 4**
Single-Family (SF)	Dwelling Units	8.05	10.56	11.98	11.98
Multi-Family Zero Cars (MF_0)	Dwelling Units	3.03	3.55	4.02	4.02
Multi-Family One Car (MF_1)	Dwelling Units	4.23	5.39	6.18	6.18
Multi-Family Two Cars (MF_2)	Dwelling Units	5.96	7.04	8.08	8.08
Multi-Family Three or More Cars (MF_3P)	Dwelling Units	7.60	8.89	10.24	10.24
Non-Residential[2]					
Land Use Type	**Units**	**2008 PlanSB Model Area Type 1**	**2008 PlanSB Model Area Type 2**	**2008 PlanSB Model Area Type 3**	**2008 PlanSB Model Area Type 4**
Commercial Services	Thousand Square-feet	100.10	115.20	128.40	128.40
Entertainment	Thousand Square-feet	36.40	43.20	48.15	48.15
Auto Related	Thousand Square-feet	16.38	17.28	19.26	19.26
Restaurant	Thousand Square-feet	100.10	139.20	136.05	136.05
Retail	Thousand Square-feet	32.76	45.18	40.28	40.28
Lodging	Thousand Square-feet	2.73	2.11	3.75	3.75

TABLE 5
DAILY VEHICLE TRIP GENERATION RATE COMPARISON
(CON'T)

Non-Residential[2]

Land Use Type	Units	2008 PlanSB Model Area Type 1	2008 PlanSB Model Area Type 2	2008 PlanSB Model Area Type 3	2008 PlanSB Model Area Type 4
Office	Thousand Square-feet	8.27	11.59	12.92	12.92
Institutional	Thousand Square-feet	45.50	48.00	53.50	53.50
Industrial	Thousand Square-feet	4.25	4.48	5.00	5.00
Hospital	Thousand Square-feet	N/A	12.48	N/A	N/A
Religious Facilities	Thousand Square-feet	8.29	8.75	9.75	9.75
Police and Fire Services	Thousand Square-feet	8.65	9.12	10.17	10.17
Elementary and Middle School	Students	1.81	1.91	2.13	2.13
High Schools	Students	N/A	0.64	N/A	0.72
Colleges	Students	N/A	0.25	0.28	N/A
Recreation (Parks and Beaches)	Relative Popularity[3]	N/A	N/A	N/A	N/A
Golf	Acres	N/A	N/A	4.75	4.75
SBCAG_Agricultural[1]	Employees	N/A	N/A	3.95	3.95
SBCAG_Industrial[1]	Employees	N/A	N/A	2.04	2.04
SBCAG_Commercial[1]	Employees	N/A	N/A	3.92	3.92
SBCAG_Office[1]	Employees	N/A	N/A	1.07	1.07
SBCAG_Service[1]	Employees	N/A	N/A	5.39	5.39

[1] The ITE manual does not stratify multifamily dwelling units by auto-ownership. ITE multifamily rates range from 4.18 to 6.72 depending on the dwelling type. Rates based on auto-ownership were developed from National Household Travel Survey (NHTS) data for the City of Santa Barbara. NHTS rates range from a minimum of 0.69 to a maximum of 11.75.

[2] Not all non-residential land use categories are present in each area type. 2008 trip generation rates were only developed for land uses present in 2008 in each area type.

[3] Recreational trips are generated at the home end (either Residential or Lodging) and distributed to the various Recreational areas of the City based on their relative popularity. Relative popularity was calibrated using count data near the recreational sites.

Source: Fehr & Peers, 2008.

Trips between the Santa Barbara Area and External Areas

One of the important inputs to a travel model is an estimate of the amount of travel between the study area and neighboring areas outside the model. These are typically called internal-external, or I-X/X-I, trips.

The United States Census Bureau surveys residential and work locations at the place level. Table 6 illustrates the distribution of work locations for Santa Barbara residents, while Table 7 illustrates the distribution of residential locations for Santa Barbara employees.

Based on this data, the proportion of HBW trips entering and leaving the study area was estimated. For non-work trip purposes, information from the SBCAG Regional Model was used to develop and initial estimate the percent of HBO and NHB trips that travel between Santa Barbara and other areas. These estimates were then refined using the City's land use database. Table 8 summarizes the proportion of trips by purpose and area type that are assumed to have one end outside the model area.

After the number of I-X/X-I trips is estimated, those trips are distributed to the stations around the perimeter of the model area using external station weights. These external station weights are based on City, County, and Caltrans traffic count data and the SBCAG Regional Model. The resulting external station weights are presented on Figure 3.

Through Trips

Through trips (also called external-external, or EE trips) are those that pass through the study area without stopping inside the study area. The major flows of through traffic in the Santa Barbara area use US-101 and SR 154, with lower volumes of through traffic using SR 192. The majority of through trips use US-101 for at least a portion of their journey, even if they do not enter or exit the model area along this route. The size of these flows was estimated based on Caltrans traffic counts and the SBCAG Regional Model. The through trips were modified in conjunction with the external station weights so that results at the gateways accurately represented observed data. The resulting through trip matrix is summarized in Table 9.

Trip Assignment

The trip assignment process determines the route that each vehicle-trip follows to travel from origin to destination. The model selects these routes in a manner that is sensitive to congestion and the desire to minimize overall travel time. It uses an iterative, capacity-restrained assignment and equilibrium volume adjustments. This technique finds a travel path for each trip that minimizes the travel time, with recognition of the congestion caused by all other trips.

The general assignment process includes the following steps:

- Assign all trips to the links along their selected paths.
- After all assignments, examine the volume on each link and adjust its impedance based on the volume-to-capacity ratio.
- Repeat the assignment process for a set number of iterations or until specified criteria related to minimizing travel delays are satisfied.

Calibration of the roadway network included modification of the centroid connectors to more accurately represent the location at which traffic accessed the local roads, adjusting speeds from the posted speed

TABLE 6 WORK LOCATIONS FOR SANTA BARBARA RESIDENTS		
Year	**Percent Working Inside Santa Barbara**	**Percent Working Outside Santa Barbara**
2000	63%	37%
Source: U.S. Census Bureau.		

TABLE 7 RESIDENTIAL LOCATIONS FOR SANTA BARBARA EMPLOYEES		
Year	**Percent Living Inside Santa Barbara**	**Percent Living Outside Santa Barbara**
2000	49%	51%
Source: U.S. Census Bureau.		

TABLE 8 PERCENT OF TRIPS BY PURPOSE THAT ARE INTERNAL/EXTERNAL FOR EACH AREA TYPE								
Purpose	**Area Type 1**		**Area Type 2**		**Area Type 3**		**Area Type 4**	
	Production	**Attraction**	**Production**	**Attraction**	**Production**	**Attraction**	**Production**	**Attraction**
Home-Based Work (HBW)	20%	41%	27%	45%	40%	49%	44%	49%
Home-Based Other (HBO)	18%	38%	19%	30%	32%	31%	20%	33%
Non-Home-Based (NHB)	21%	21%	21%	20%	23%	24%	21%	24%
Golf (GOLF)	0%	40%	0%	40%	0%	35%	0%	35%
Recreational (REC)	0%	30%	0%	30%	0%	20%	0%	20%
Source: Fehr & Peers, 2008.								

Gateway Number	Gateway Description	Gateway Weight
1001	Hollister Avenue west of Turnpike Road	6.9%
1002	US-101 west of Turnpike Road	41.7%
1003	US-101 SB west of Turnpike Road (not used - combined with 1002)	0.0%
1004	Cathedral Oaks Road west of Turnpike Road	5.6%
1005	State Route 154 north of State Route 192	7.1%
1006	State Route 192 west of Sheffield Drive	3.1%
1007	Sheffield Drive north of Ortega Hill Road	2.0%
1008	Ortega Hill Road east of Ortega Ridge Road	0.8%
1009	US-101 east of Sheffield Drive	32.8%
1010	US-101 SB east of Sheffield Drive (not used - combined with 1009)	0.0%

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PLAN SANTA BARBARA EXTERNAL STATION WEIGHTS

FIGURE 3

TABLE 9 MATRIX OF DAILY THROUGH (EE) TRIPS							
Destination **Origin**	Hollister Ave west of Turnpike Rd	Hwy 101 west of Turnpike Rd	Cathedral Oaks Rd west of Turnpike Rd	Hwy 154 north of Hwy 192	Ortega Hill Rd north of Ortega Ridge Rd	Hwy 101 east of Sheffield Dr	**Total**
Hollister Ave west of Turnpike Rd		0	0	0	55	265	**320**
Hwy 101 west of Turnpike Rd	0		0	0	285	10120	**10405**
Cathedral Oaks Rd west of Turnpike Rd	0	0		0	30	75	**105**
Hwy 154 north of Hwy 192	0	0	0		30	830	**860**
Ortega Hill Rd east of Ortega Ridge Rd	55	285	30	30		0	**400**
Hwy 101 east of Sheffield Dr	265	10120	75	830	0		**11,290**
Total	**320**	**10405**	**105**	**860**	**400**	**11,290**	**23,380**

Note: All trips are rounded to the nearest 5 and external gateways with less than 100 trips are not shown on the above table.
Source: SBCAG

limit to adjust the attractiveness of the route and better reflect the prevailing speed of traffic, and refining the turn penalties.

Turn Penalties

Turn penalties are used to prohibit or add delay to certain turning movements. The Santa Barbara model prohibits traffic from getting off a freeway ramp and then immediately getting back on, as well as prohibits traffic from making turns across a median. In addition, all U-turns are prohibited throughout the model area in order to avoid counter-intuitive traffic routing. The PM peak hour assignment also prohibits left turns onto and off of State Street in the Central Business District.

MODEL VALIDATION

Model validation is the term used to describe model performance in terms of how closely the model's output matches existing travel data in the base year. During the model development process, these outputs are used to further calibrate the model inputs. The extent to which the model outputs match existing travel data validates the assumptions of the inputs.

Traditionally, most model validation guidelines focus on the performance of the trip assignment function in accurately assigning trips to the roadway network. This is called static validation. This metric remains the most common and widely used means to measure model accuracy.

However, models are seldom used for static applications; by far the most common use of models is to forecast how a change in inputs would result in a change in traffic conditions. Therefore, another test of a model's accuracy focuses on the model's ability to predict realistic differences in outputs as inputs are changed; or "dynamic" validation rather than static validation. In other words, it is good engineering practice take the model for a "test drive." This section describes the highest level validation checks that have been performed for the 2008 Santa Barbara TDF model.

STATIC VALIDATION

The most critical static measurement of the accuracy of any travel model is the degree to which it can approximate actual traffic counts in the base year. Caltrans has established certain trip assignment guidelines for models to be deemed acceptable for forecasting future year traffic in Travel Forecasting Guidelines (California Department of Transportation, November 1992). The validity of the PlanSB model was tested for daily, AM peak hour, and PM peak hour conditions. Model volumes were compared to existing traffic counts at 159 individual count sites for the daily validation, and 187 count sites for the AM and PM peak hour validation. The results are shown in Tables 10 through 11.

Link volume results from the model runs were examined and checked for reasonableness. Links were identified where model results varied substantially from the observed counts, and the characteristics of those links were reviewed to ensure that the link attributes reflected local operating conditions. In some cases, link characteristics such as speeds were modified to better reflect conditions on the ground.

Comparison Techniques

Travel model accuracy is usually tested using four comparison techniques:

- The volume-to-count ratio is computed by dividing the volume assigned by the model and the actual traffic count for individual roadways (or intersections) area-wide.
- The maximum deviation is the difference between the model volume and the actual count divided by the actual count.
- The correlation coefficient estimates the correlation between the actual traffic counts and the estimated traffic volumes from the model.
- The percent root mean square error (RMSE) is the square root of the model volume minus the actual count squared divided by the number of counts. It is a measure similar to standard deviation in that it assesses the accuracy of the entire model.

TABLE 10 RESULTS OF DAILY MODEL VALIDATION		
Validation Item	**Criterion for Acceptance**	**Model Results**
Count Locations	N/A	159
% of Links Within Caltrans Standard Deviations	At Least 75%	77%
% of Screenlines Within Caltrans Standard Deviations	100%	100%
2-way Sum of All Links Counted	Within ± 10%	9%
Correlation Coefficient	Greater than 88%	99%
RMSE	40% or less	23%
Source: Fehr & Peers, 2008.		

TABLE 11 RESULTS OF PEAK HOUR MODEL VALIDATION			
Validation Item	**Criterion for Acceptance**	**AM Peak Hour Model Results**	**PM Peak Hour Model Results**
Count Locations	N/A	187	187
% of Links Within Caltrans Standard Deviations	At Least 75%	77%	78%
% of Screenlines Within Caltrans Standard Deviations	100%	100%	100%
2-way Sum of All Links Counted	Within ± 10%	3%	3%
Correlation Coefficient	Greater than 88%	90%	91%
RMSE	40% or less	29%	28%
Source: Fehr & Peers, 2008.			

Validation Guidelines

For a model to be considered accurate and appropriate for use in travel forecasting, it must replicate actual conditions within a certain level of accuracy. Since it would be impossible for any model to replicate all counts precisely, validation guidelines have been established by Caltrans and other agencies. Key validation standards for daily travel models based on the Caltrans guidelines are summarized below:

- At least 75 percent of the roadway links for which counts are available should be within the maximum desirable deviation, which ranges from approximately 15 to 60 percent depending on total volume (the larger the volume, the less deviation is permitted).
- All of the roadway screenlines should be within the maximum desirable deviation, which ranges from approximately 15 to 64 percent depending on total volume.
- The two-way sum of the volumes on all roadway links for which counts are available should be within 10 percent of the counts.
- The correlation coefficient between the actual ground counts and the estimated traffic volumes should be greater than 88 percent.

Although not stated in the Caltrans standards, an additional Fehr & Peers validation guideline was applied to the 2008 PlanSB model:

- The RMSE should not exceed 40 percent.

Tables: Results of Daily and Peak Hour Validation

DYNAMIC VALIDATION

The traditional approach to the validation of travel demand models is to compare the link volumes for the model's base year to actual traffic counts taken in the same year. This approach provides information on a model's ability to reproduce a static condition. While reproducing these conditions is very important, it is also important to know that the model will produce stable and reasonable results when various inputs such as land use are changed. The following section presents a selection of the dynamic validation results

Land Use Changes

A basic form of dynamic validation is to vary the amounts of a particular land use type and compare the magnitude and direction of change from the original forecast. Of particular interest are the resulting changes in:

- Vehicle Trips (VT)
- Change in VT per land use unit change (VT/DU or KSF)
- Vehicle Miles Traveled (VMT)
- Change in VMT per land use unit change (VMT/DU or KSF)
- Vehicle Hours Traveled (VHT)
- Change in VHT per land use unit change (VHT/DU or KSF)
- Vehicle miles traveled per vehicle trip (VMT/VT)

This form of dynamic validation was performed on the Santa Barbara model by adjusting the number of multi-family one car dwelling units and the retail development in TAZs 41, 320, 370, and 297. These zones were selected due to their geographic location, the existing land use mix within the zone, and to test one zone from each of the four area types. To isolate each of these changes, tests were done sequentially, changing one item at a time.

Figure 4 shows the location of the zones that were used for dynamic validation. Zone 41 is located downtown near Chapala Street/Ortega Street and contains a broad mix of residential and non-residential land uses. Zone 320 is located in the Westside and contains residential and retail land uses. Zone 370 is located on the Riviera and contains single family land uses and an elementary school. Zone 297 is located in the Upper State Street Area and contains a broad mix of residential and non-residential land uses. The values added to a zone were selected based on the interaction with adjacent land use, and to determine if the model is sensitive to the location and magnitude of various land use changes. The results are shown in Table 12.

- The change in VT per added DU ranges from 3.0 – 5.0. This is reasonable given the mix of land uses in the various zones and the different trip generation rates of each area type. Within each individual area type there is very little variability, showing stable trip generation across the range of land use magnitudes. The average vehicle trips per added DU are lowest for zone 41 due to the abundance of other land uses for the residents to interact with.

- Adding a single DU to the model is a test of how much noise (random error) is in the model. Total VMT changed by between 9 and 229 vehicle-miles per day per dwelling unit added, depending on the zone it was added to. Three of the four zones behaved very well with zones 41, 370 and 297 showing the appropriate increases in VMT relative to the land use mix surrounding these zones. Zone 41 has the lowest increase in VMT, while zone 370 has the highest and zone 297 falls in between. Only zone 320 returns unreasonable results. However, with only a modest increase in dwelling units in this zone, representing a realistic level of development, the model performed as expected.

- The VHT per DU change is fairly stable around -1.0 to 1.4, with the exception of adding to zone 320. However, the noise at this extremely small level of change is no longer present if increased to a normal level of development.

- As shown in Table 12, the VMT/VT is very stable and typically is around 4.2. This measure is used to reduce the influence of vehicle trip generation differences between land use types by normalizing the trip distance by total trips. As land use is added near existing compatible uses, the distance traveled decreases slightly. The opposite is also true: as land use is removed from nearby uses or added further from compatible uses, the distance traveled increases.

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PLAN SANTA BARBARA TAZs USED FOR DYNAMIC VALIDATION

FIGURE 4

TABLE 12 RESULTS OF DYNAMIC VALIDATION TESTS								
TAZ	**Scenario**	**Vehicle Trips (VT)**	**Change in VT/DU or KSF Change**	**Vehicle Miles Traveled (VMT)**	**Change in VMT/DU or KSF Change**	**Vehicle Hours Traveled (VHT)**	**Change in VHT/DU or KSF Change**	**VMT/VT**
Residential Land Use Results - Multifamily Unit with 1 Car								
Base Case		595,479	N/A	2,500,894	N/A	59,668	N/A	4.20
41 - Downtown	Added 1 DU	595,482	3.0	2,500,903	9.0	59,667	-1.0	4.20
	Added 25 DUs	595,557	3.1	2,501,338	17.8	59,690	0.9	4.20
	Added 50 DUs	595,635	3.1	2,501,440	10.9	59,698	0.6	4.20
320 - Westside	Added 1 DU	595,483	4.0	2,501,123	229.0	59,680	12.0	4.20
	Added 25 DUs	595,581	4.1	2,501,403	20.4	59,695	1.1	4.20
	Added 50 DUs	595,683	4.1	2,501,683	15.8	59,706	0.8	4.20
370 - Riveria	Added 1 DU	595,484	5.0	2,500,913	19.0	59,669	1.0	4.20
	Added 25 DUs	595,595	4.6	2,501,488	23.8	59,707	1.6	4.20
	Added 50 DUs	595,712	4.7	2,501,935	20.8	59,713	0.9	4.20
297 - Upper State Street	Added 1 DU	595,484	5.0	2,500,906	12.0	59,668	0.0	4.20
	Added 25 DUs	595,595	4.6	2,501,485	23.6	59,702	1.4	4.20
	Added 50 DUs	595,711	4.6	2,501,968	21.5	59,703	0.7	4.20
Retail Land Use Results								
Base Case		595,479	N/A	2,500,894	N/A	59,668	N/A	4.20
41 - Downtown	Added 1 KSF	595,499	20.0	2,501,174	280.0	59,683	15.0	4.20
	Added 10 KSF	595,684	20.5	2,501,615	72.1	59,710	4.2	4.20
	Added 50 KSF	596,501	20.4	2,504,277	67.7	59,816	3.0	4.20

TABLE 12
RESULTS OF DYNAMIC VALIDATION TESTS
(CON'T)

TAZ	Scenario	Vehicle Trips (VT)	Change in VT/DU or KSF Change	Vehicle Miles Traveled (VMT)	Change in VMT/DU or KSF Change	Vehicle Hours Traveled (VHT)	Change in VHT/DU or KSF Change	VMT/VT
Retail Land Use Results								
320 - Westside	Added 1 KSF	595,502	23.0	2,501,190	296.0	59,686	18.0	4.20
	Added 10 KSF	595,707	22.8	2,501,932	103.8	59,706	3.8	4.20
	Added 50 KSF	596,618	22.8	2,505,330	88.7	59,852	3.7	4.20
370 - Riveria	Added 1 KSF	595,550	71.0	2,501,174	280.0	59,685	17.0	4.20
	Added 10 KSF	595,686	20.7	2,501,955	106.1	59,708	4.0	4.20
	Added 50 KSF	596,513	20.7	2,505,378	89.7	59,828	3.2	4.20
297 - Upper State Street	Added 1 KSF	595,501	22.0	2,501,204	310.0	59,684	16.0	4.20
	Added 10 KSF	595,702	22.3	2,504,967	407.3	59,721	5.3	4.21
	Added 50 KSF	596,594	22.3	2,505,739	96.9	59,868	4.0	4.20

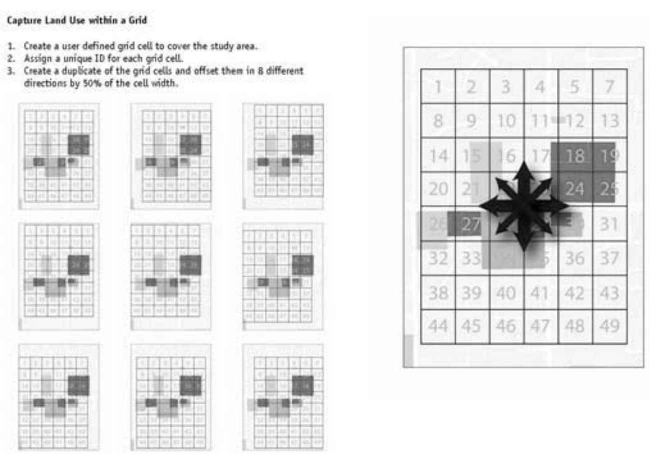
Source: Fehr & Peers, 2008.

THE 4D PROCESS

The Ds method (commonly known as the 4Ds, although later expanded to include more than four built environment factors) will allow the City to evaluate the transportation effects of *Plan Santa Barbara Framework* policies, and to identify potential site-plan refinements that will further reduce its traffic impacts. The methods are based on a substantial library of research on the relationship between travel and the built environment, which has been distilled to a single set of numerical values by a panel of national experts.

The Ds will predict the degree to which each Plan Santa Barbara horizon-year land use scenario's trip generation will increase or decline with changes to the plan's:

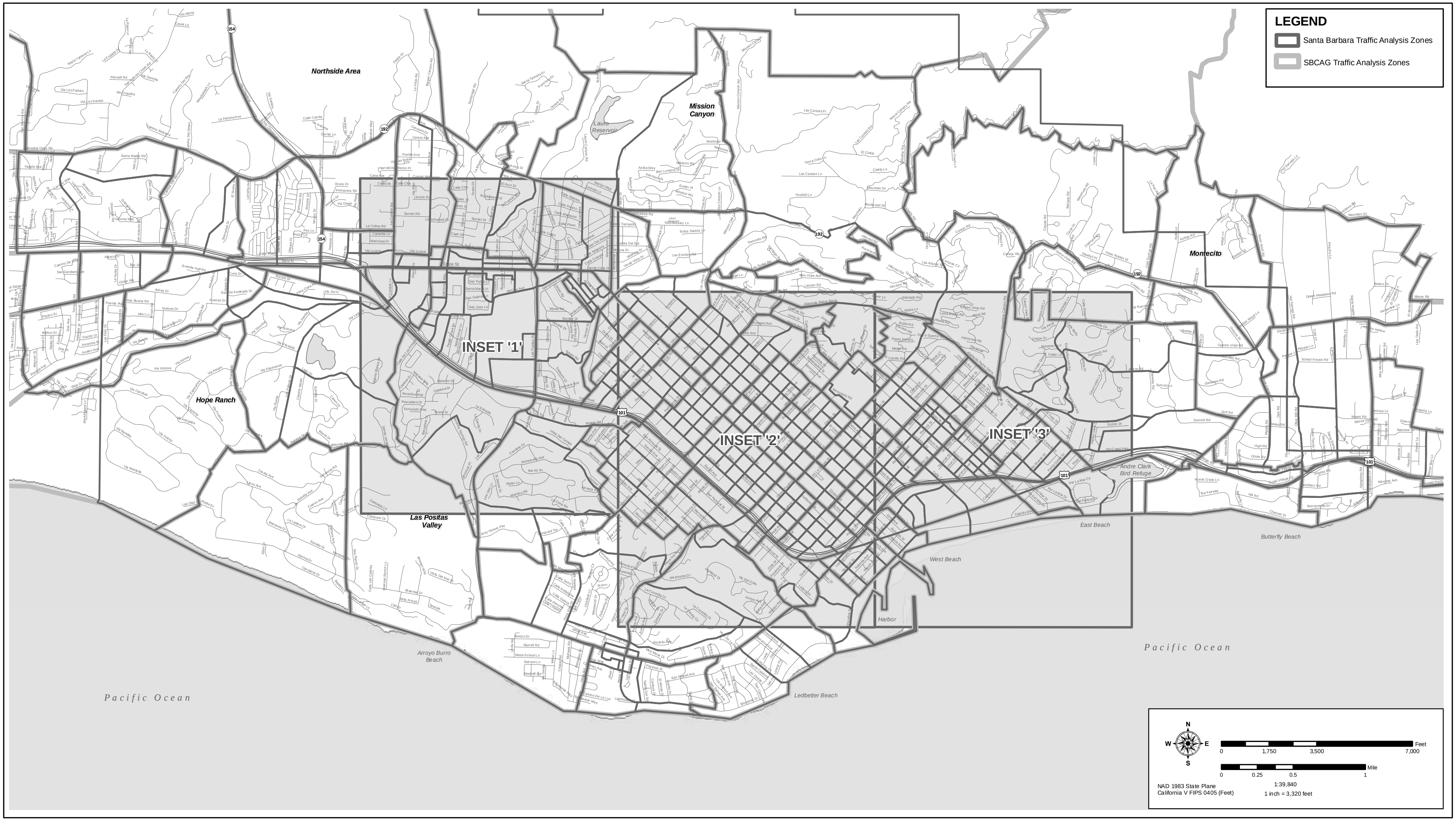
- Density - residential and non-residential development per acre;
- Diversity - mix of residential, retail and employment land uses on the site;
- Design - connectivity and walkability of the site's transportation networks; and
- Destination Accessibility - location relative to major regional attractions, as infill sites generate fewer and shorter vehicle trips than fringe area development.



The Santa Barbara travel demand model will include advanced features that allow it to better capture the effects of *Plan Santa Barbara Framework* policy options. These features include:

- Integrated 4D refinements to enhance the sensitivity of the model to account for how travel behavior is affected by the built environment, which are necessary for evaluating the change in vehicle trips and vehicle miles of travel associated with infill development.
- GIS-based ¼ mile grid-cell analysis for calculating 4D variables for input into the traffic model. The grid-cell approach uses parcel-level land use to increase the accuracy of the variable estimates by capturing all land use intersections in ¼ grids. This method is superior to calculating variables based on traffic analysis zone geography, which can be too large to capture many nuances of the built environment.
- Refined multi-family household trip generation structure cross-classified by automobile ownership.
- Trip assignment that isolates drive alone and shared ride (2 and 3+) trips by purpose.
- District-based TDF model structure to capture different travel characteristics in different areas of the City.
- Refined TAZ system in high activity areas to allow for detailed traffic assignment.

APPENDIX A:
TRAFFIC ANALYSIS ZONES KEY MAP



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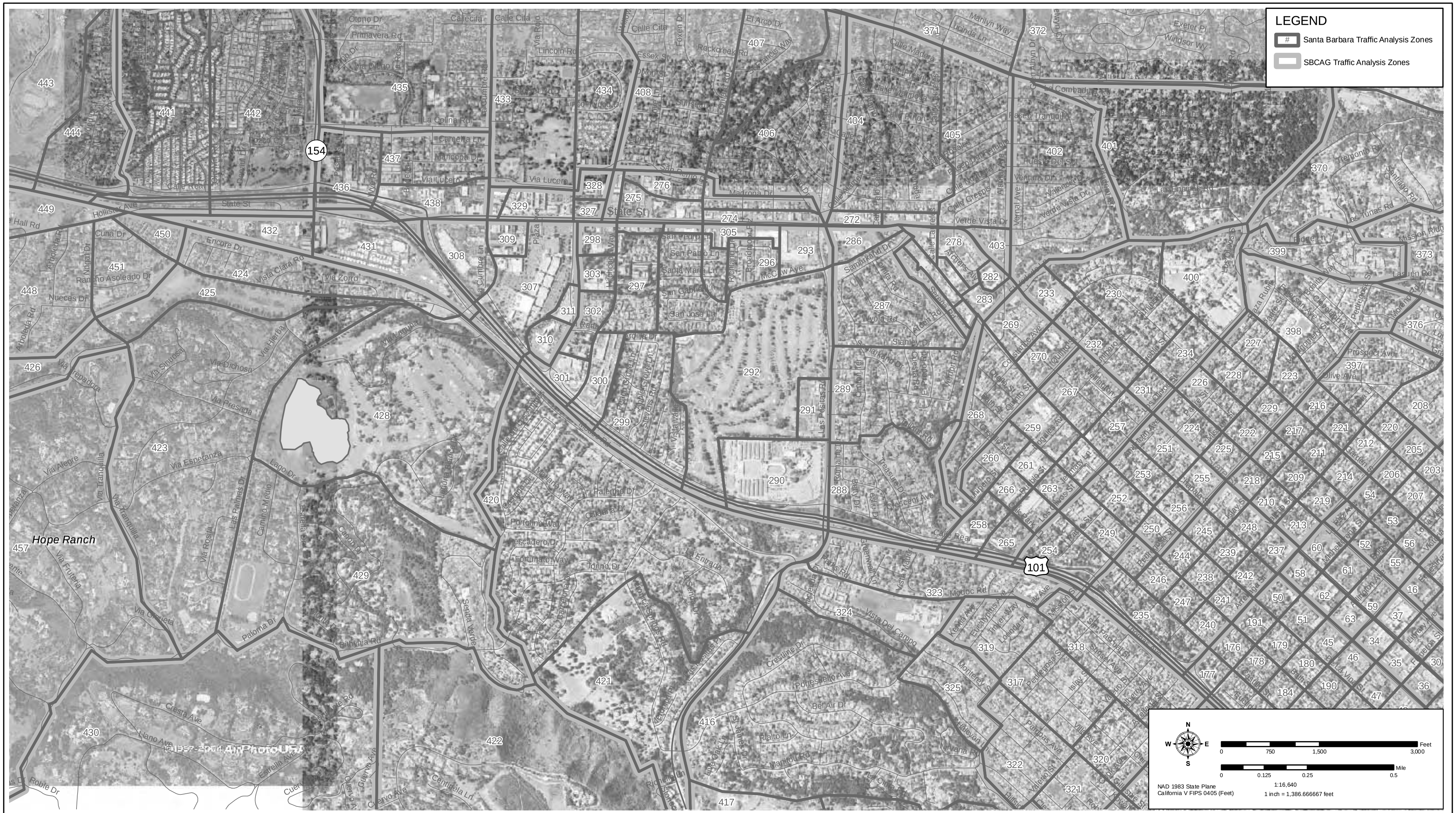
PLAN SANTA BARBARA TRAFFIC ANALYSIS ZONES - KEY MAP

APPENDIX A



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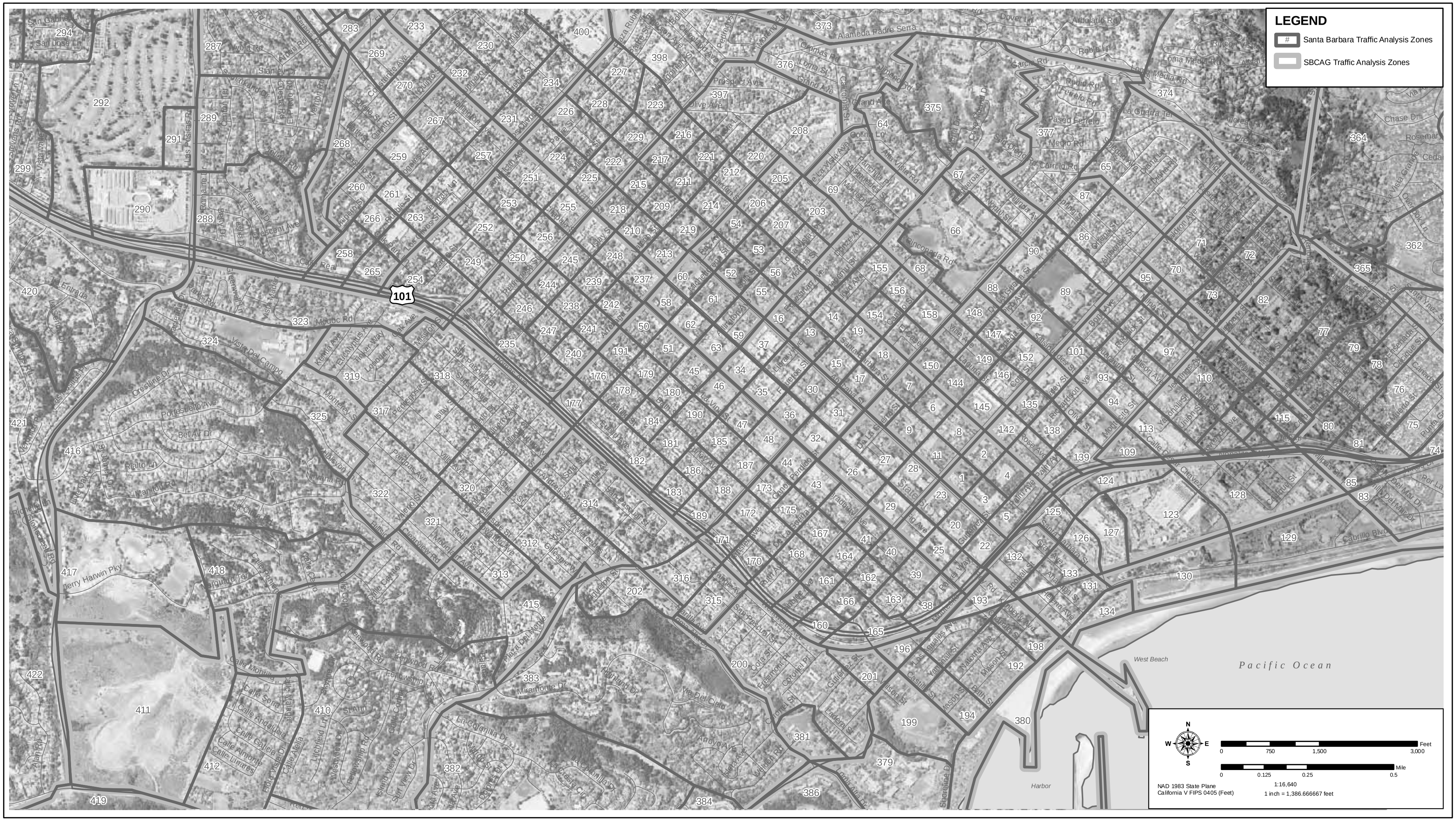
PLAN SANTA BARBARA TRAFFIC ANALYSIS ZONES
INSET 1



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PLAN SANTA BARBARA TRAFFIC ANALYSIS ZONES
INSET 2

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PLAN SANTA BARBARA TRAFFIC ANALYSIS ZONES
INSET 3

APPENDIX B:
SAMPLE ITE TRIP GENERATION RATES

APPENDIX B

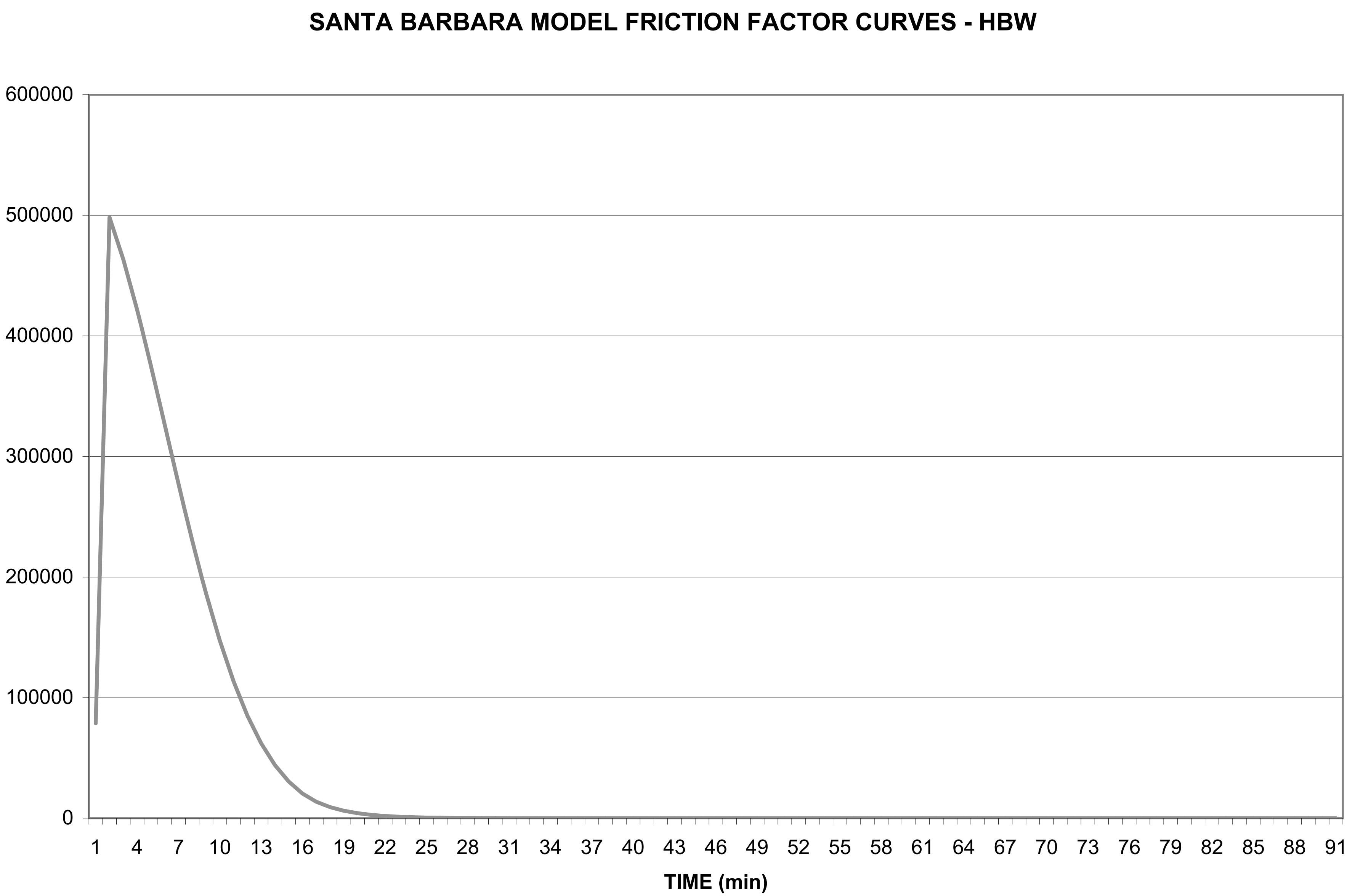
SAMPLE ITE TRIP GENERATION RATES[1]

Land Use Type	Units	Rate
Residential		
Land Use Type	**Units**	**Rate**
Single-Family (SF)	Dwelling Units	9.57
Apartment	Dwelling Units	6.72
Residential Condominium/Townhouse	Dwelling Units	5.86
Non-Residential		
Land Use Type	**Units**	**Rate**
Office	Thousand Square-feet	11.01
General Light Industrial	Thousand Square-feet	6.97
Hospital	Thousand Square-feet	17.57
Elementary chool	Students	1.29
High Schools	Students	1.71
Junior/Community Colleges	Students	1.20
Golf	Acres	5.04

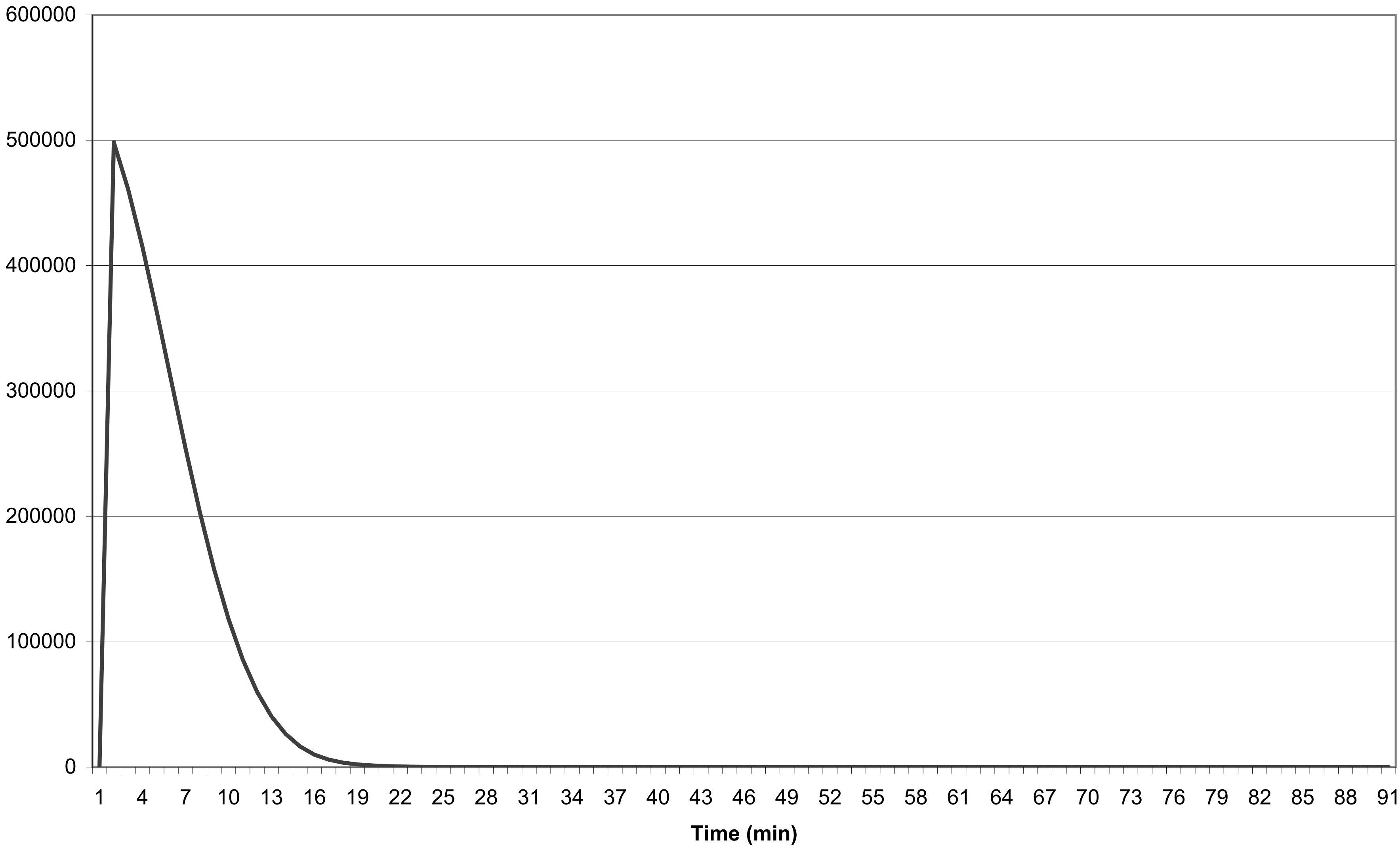
[1] ITE trip generation rates are provided for land use categories that are closely comparable between the model and ITE definitions. In general, ITE categories are more specific than the model land use categories and a direct comparison is not possible.

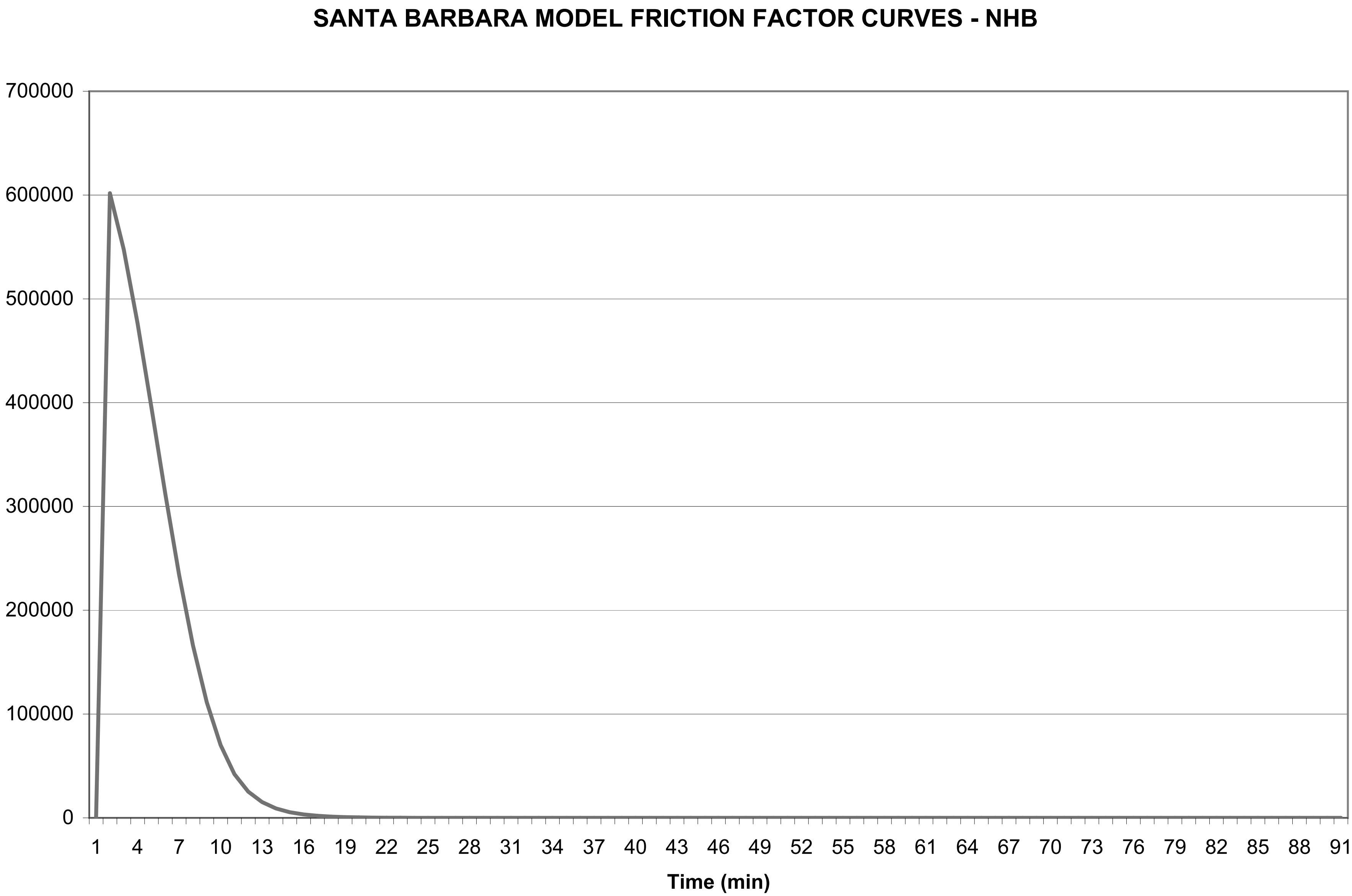
Source: Trip Generation, 7th Edition (Institute of Transportation Engineers, 2003)

APPENDIX C:
SANTA BARBARA MODEL FRICTION FACTOR CURVES-HBW

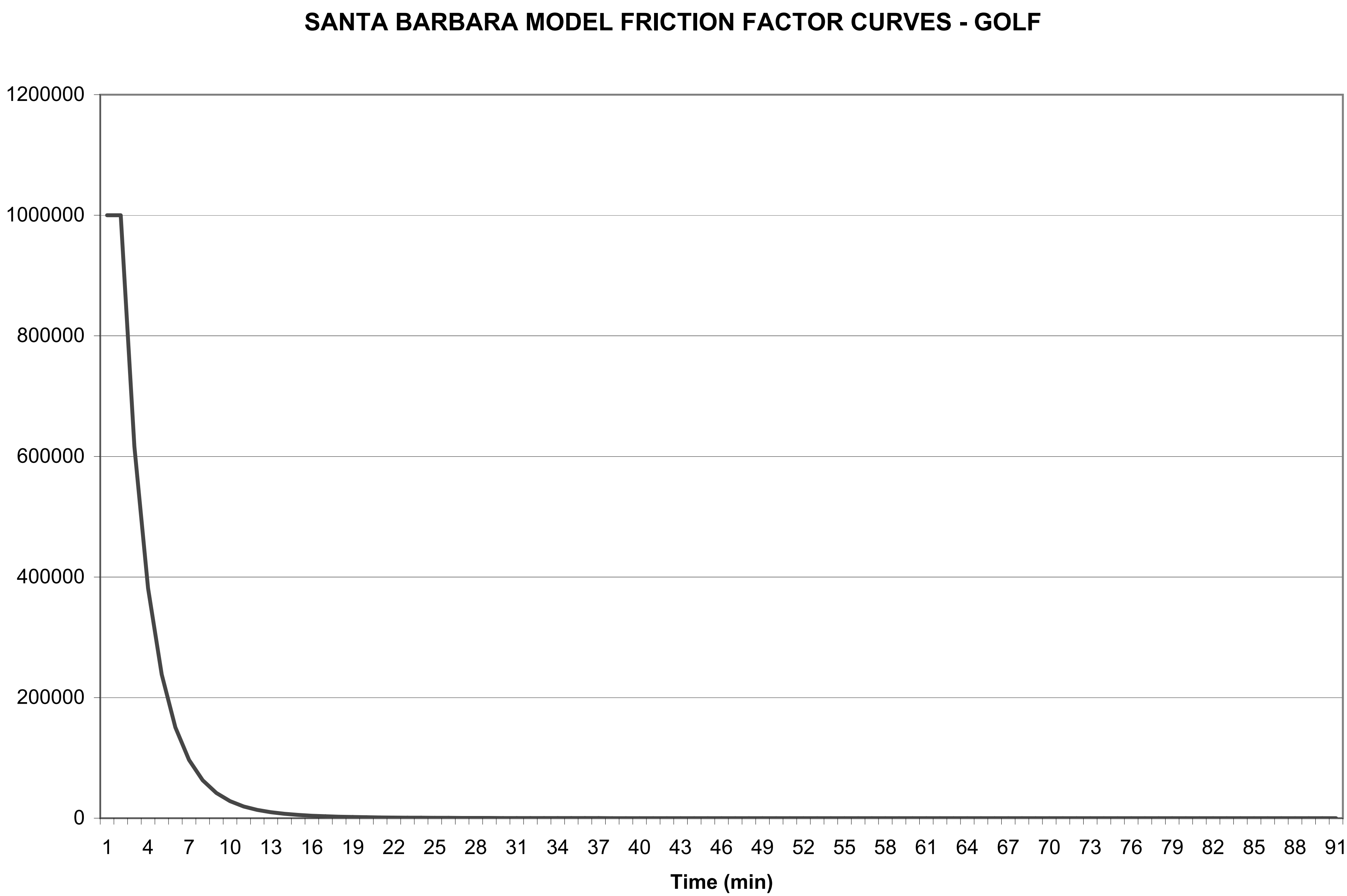

SANTA BARBARA MODEL FRICTION FACTOR CURVES - HBW
600000
500000
400000
300000
200000
100000
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
TIME (min)

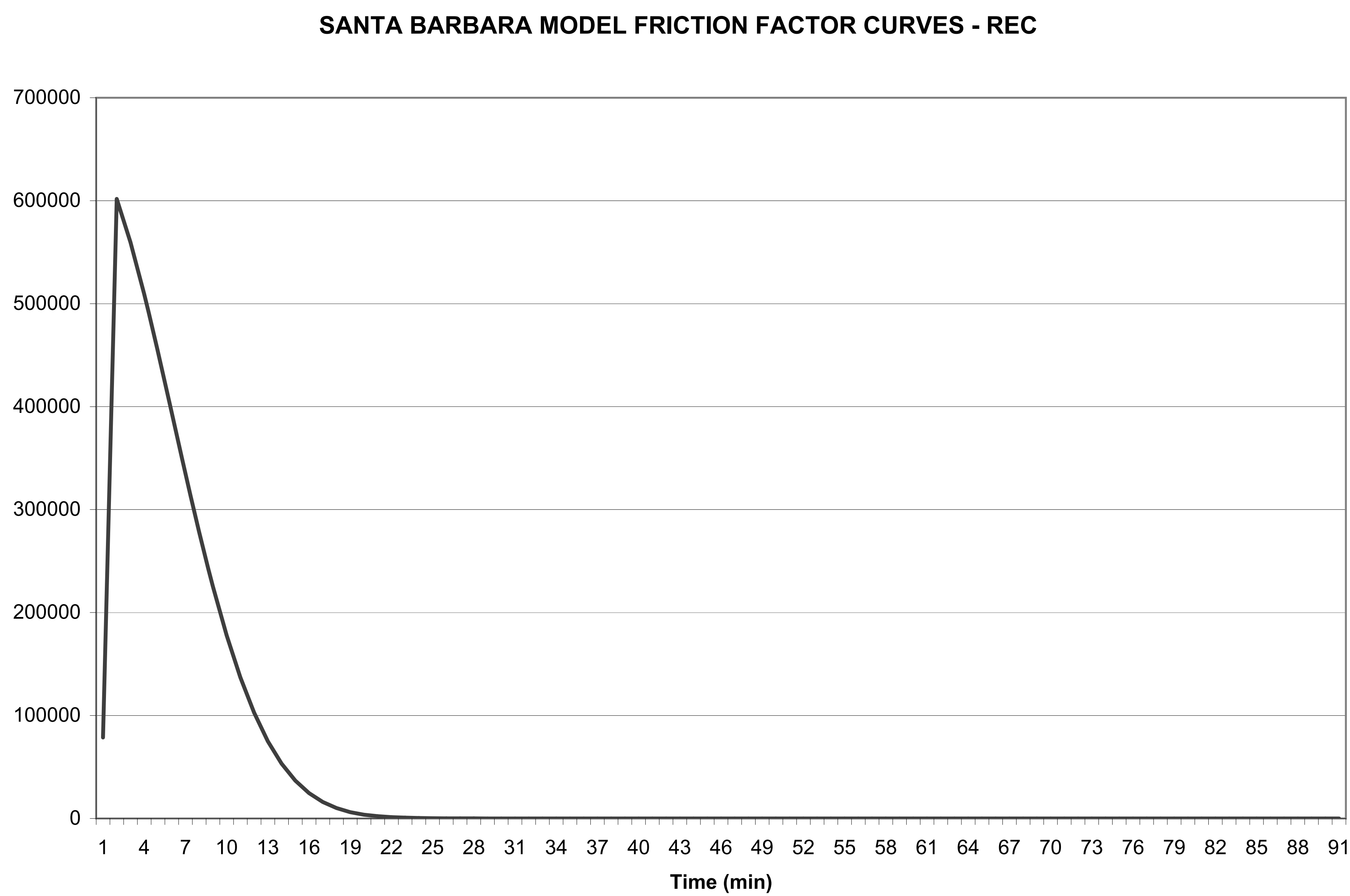
SANTA BARBARA MODEL FRICTION FACTOR CURVES - HBO





SANTA BARBARA MODEL FRICTION FACTOR CURVES - NHB
700000
600000
500000
400000
300000
200000
100000
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91
Time (min)


SANTA BARBARA MODEL FRICTION FACTOR CURVES - GOLF
1200000
1000000
800000
600000
400000
200000
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91
Time (min)


SANTA BARBARA MODEL FRICTION FACTOR CURVES - REC
700000
600000
500000
400000
300000
200000
100000
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
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55
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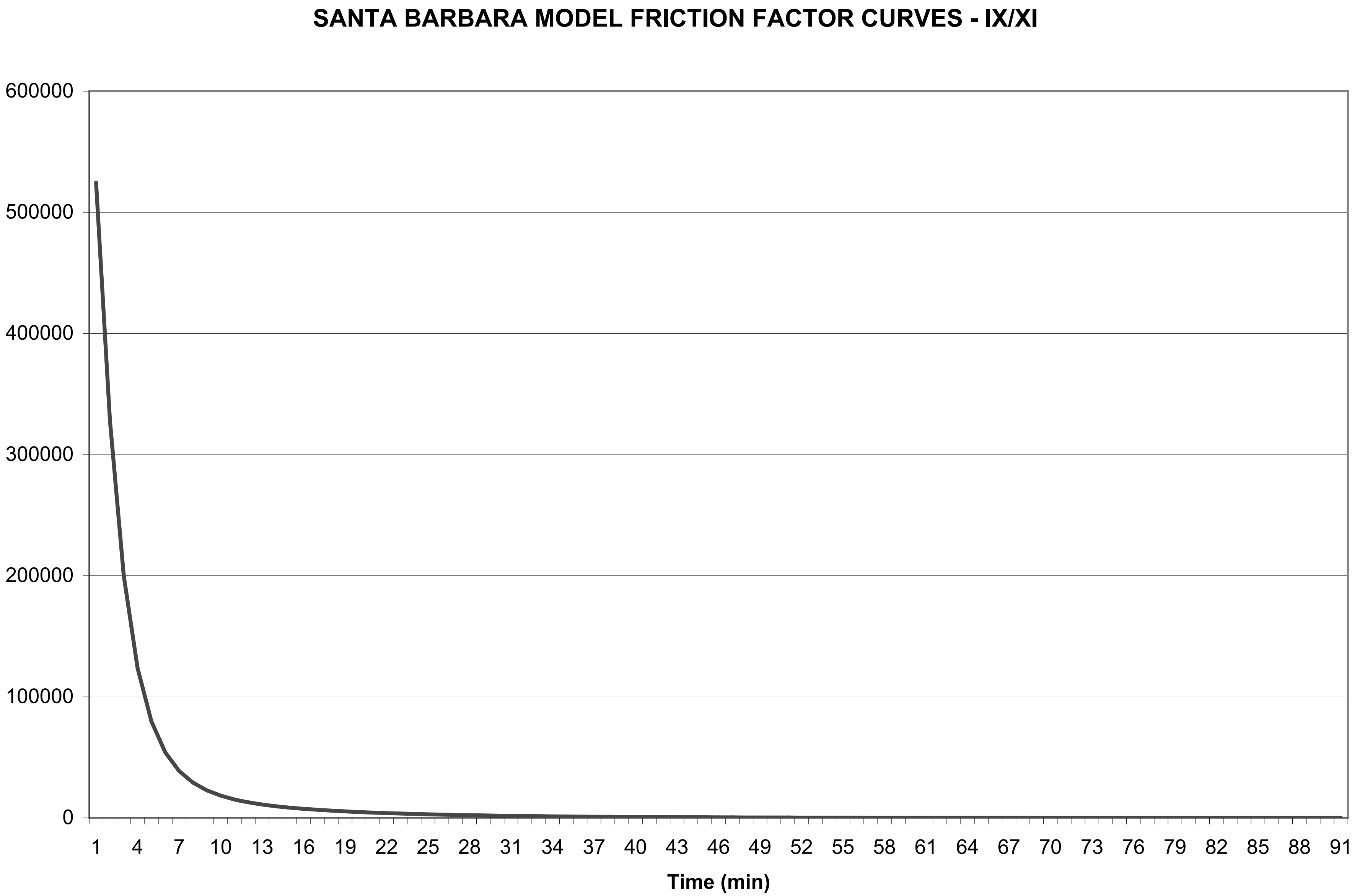
67
70
73
76
79
82
85
88
91
Time (min)


SANTA BARBARA MODEL FRICTION FACTOR CURVES - IX/XI
600000
500000
400000
300000
200000
100000
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91
Time (min)